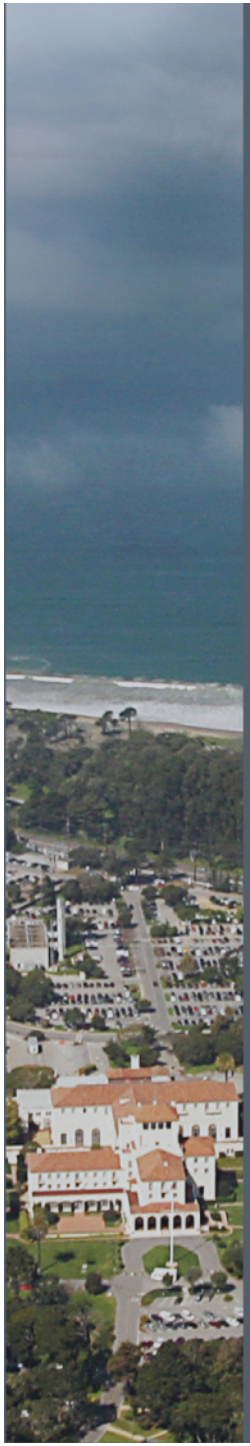
2011

SMART underwater robot (SUR) application and mining

Chu, P.C.

Chu, P.C., SMART underwater robot (SUR) application and mining. World Ocean Forum 2011, BEXCO, Busan, South Korea, 26-28 October 2011 (invited).



World Ocean Forum 2011
Oct 26-28, Busan, Korea

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SMART Underwater Robot (SUR) Application & Mining

Peter C. Chu

pcchu@nps.edu

http://faculty.nps.edu/pcchu

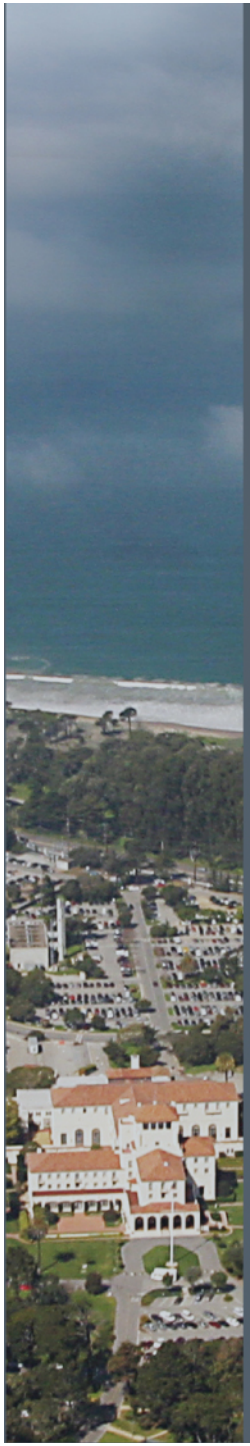
Outline

(1) Undersea Resources and Mining

- Facts
- Undersea Mining Procedure
- Undersea Mining Vessels
- Difficulties in Undersea Mining

(2) Smart Underwater Robot Technology

- Why SMART Underwater Robot (SUR)?
- Ingredients of Smartness
- SMART Underwater Robot System
- Future Prospective for Undersea Mining



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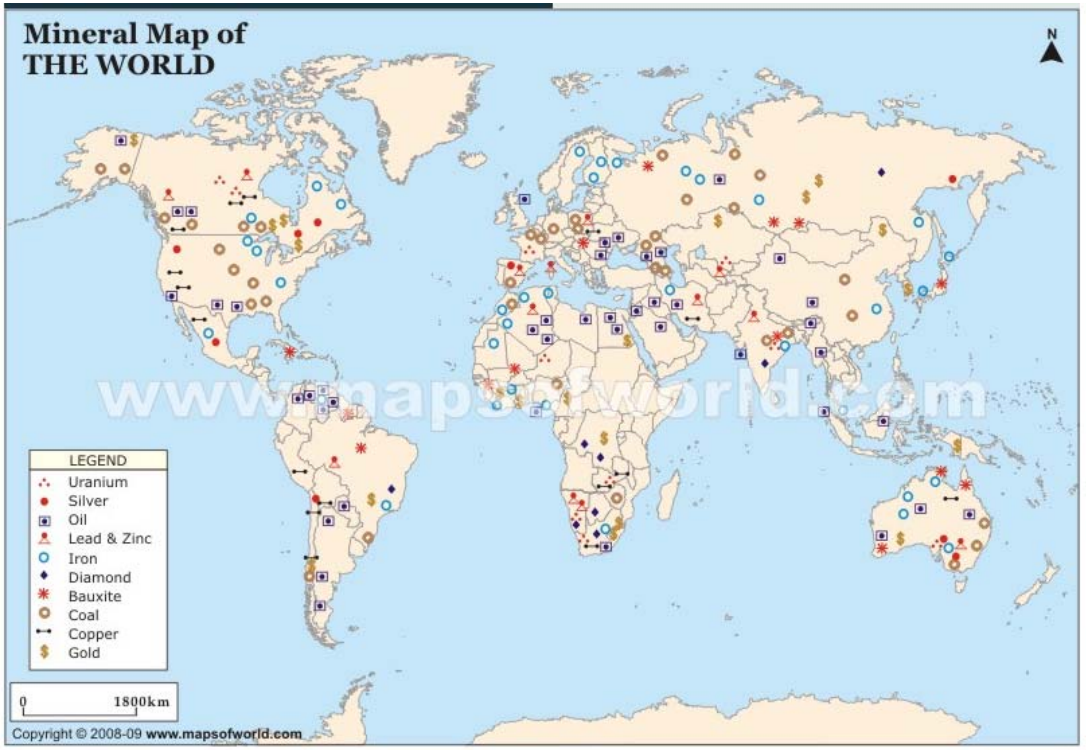
(1) Undersea Resources and Mining

Facts

Undersea Resources and Mining

Land Resources

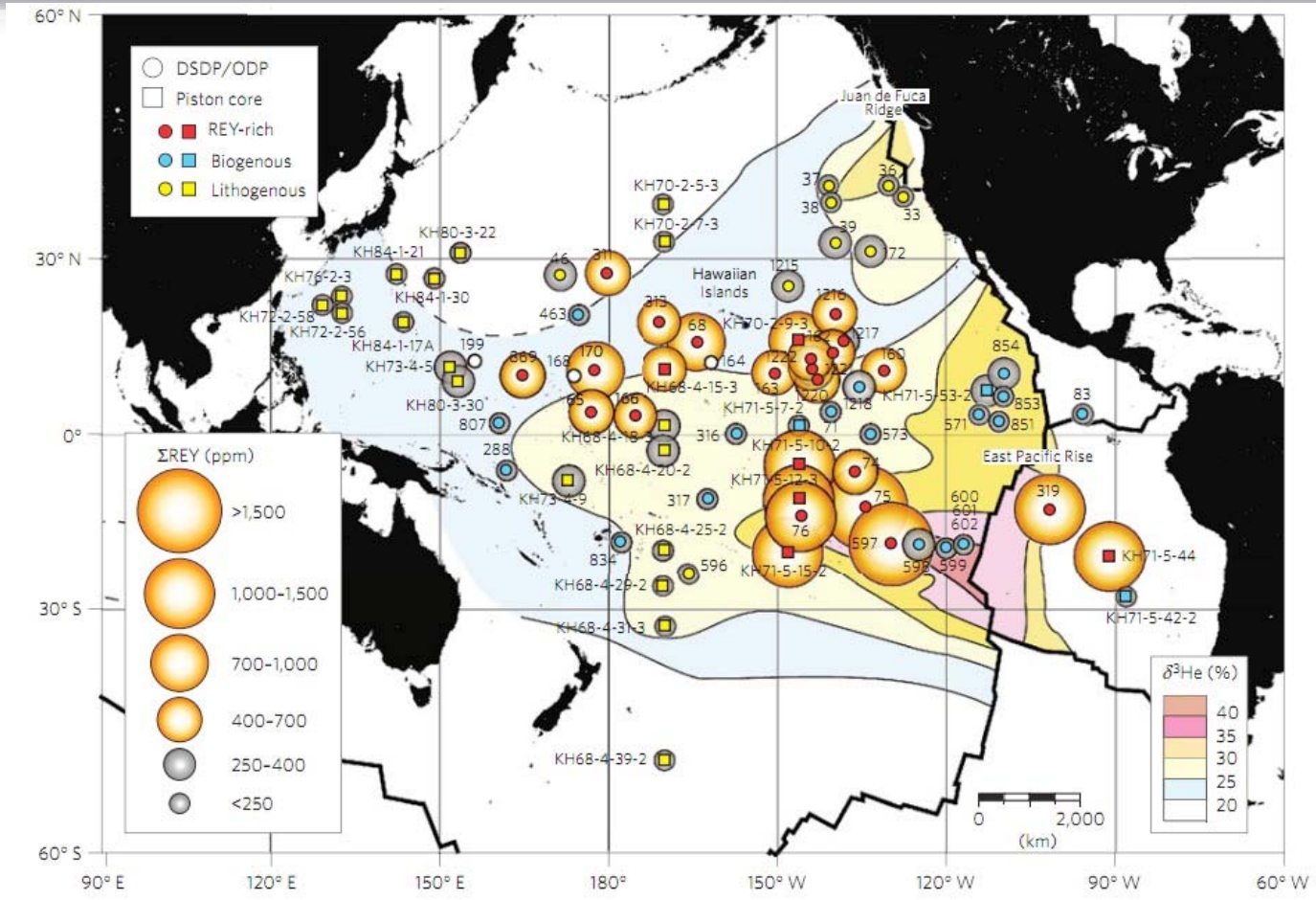


Land resources are depleted and vanished

Marine environment covers more than 70 % of the Earth

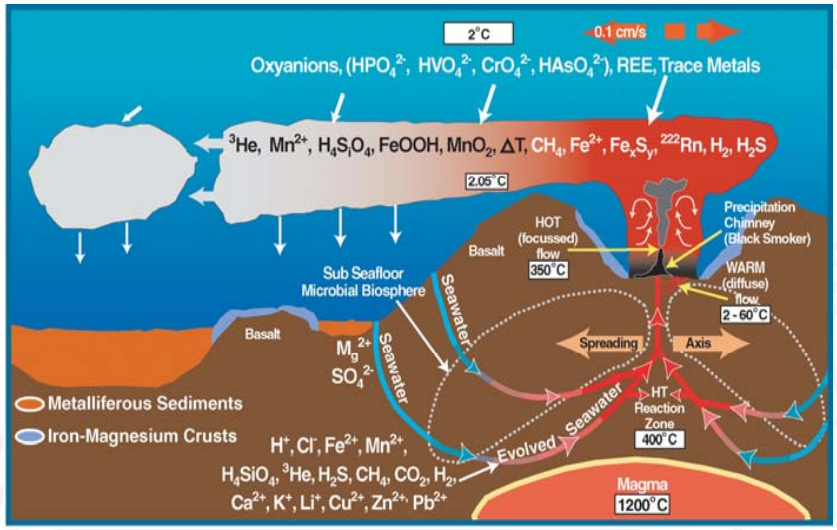
Future for the mankind

Facts



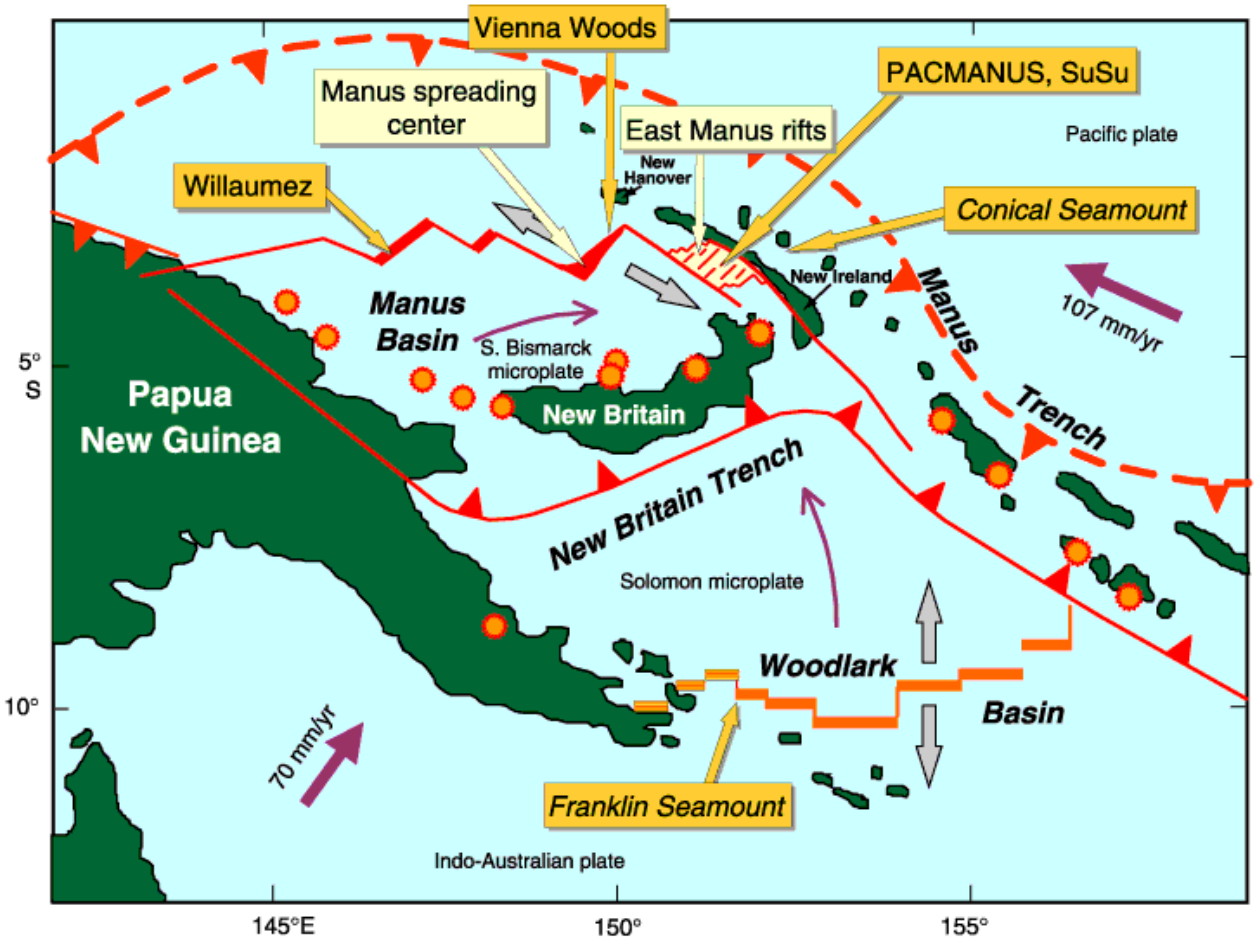
Rare earth element deposits in the Pacific Ocean less than 2 km deep (University of Tokyo, 2007)

Minerals and Related Depths



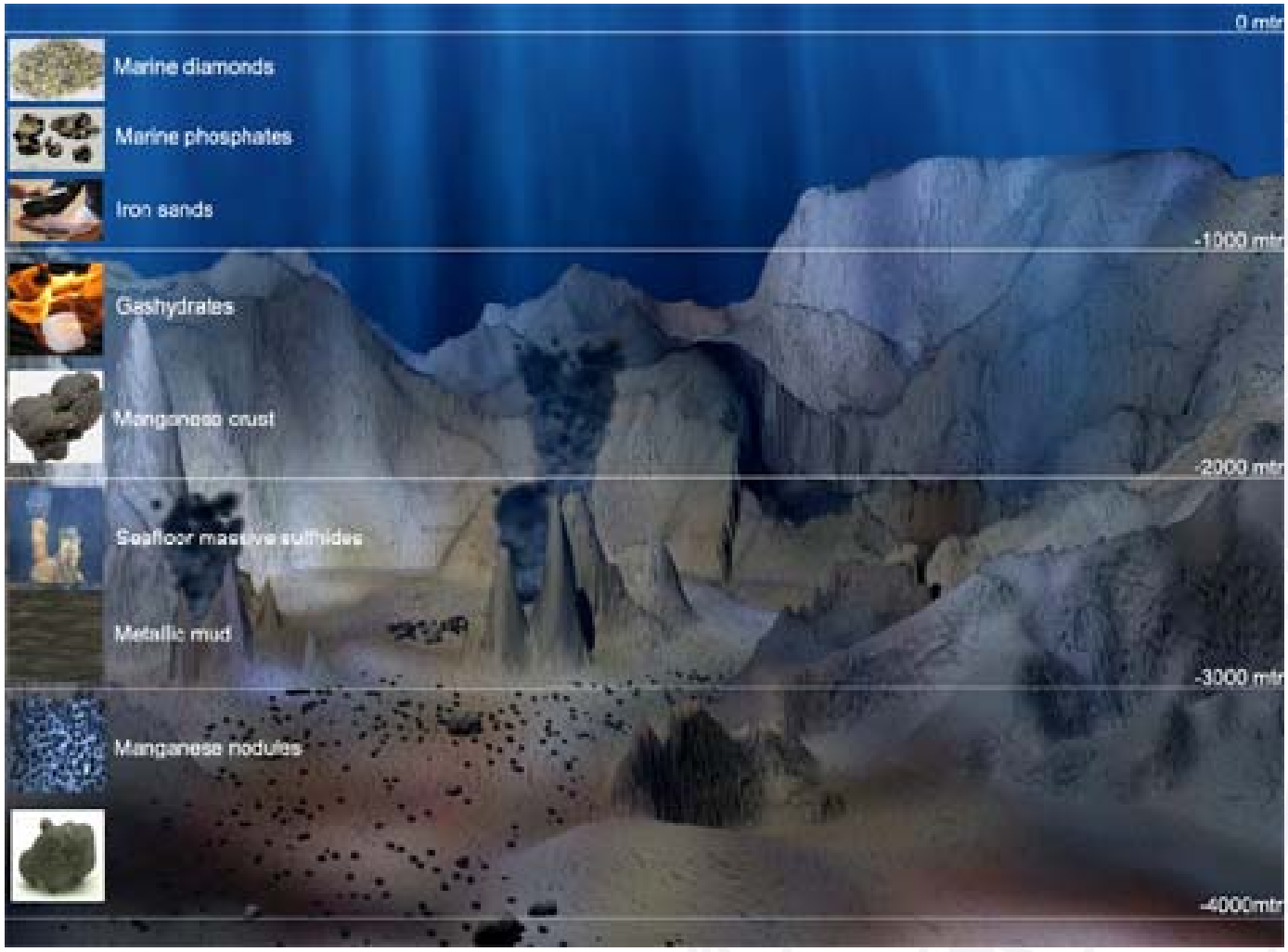
Type of Mineral Deposit	Average Depth	Resources Found
Polymetallic Nodules	4,000 - 6,000 m	Nickel, Copper, Cobalt, and Manganese
Manganese Crusts	800 - 2,400 m	Mainly Cobalt, some Vanadium, Molybdenum and Platinum
Sulfide Deposits	1,400 - 3,700 m	Copper, Lead and Zinc some Gold and Silver

Facts



Hydrothermal Vent Formation & the Formation of Seafloor Massive Sulfides (Birney et al., 2007)

Ocean Resources



Surface

- 1,000 m

- 2,000m

- 3,000m

- 4,000m

Precious Metals

Image : Precious Metals from Deep-Sea Vents

Active hydrothermal vents at Roman Ruins vent in the PACMANUS vent field, eastern Manus Basin. (Photo courtesy M. Tivey and WHOI Deep Submergence Lab, Cruise Manus 2006 with ROV Jason II)

Underwater Mining Procedure

Search/Explore

Location of Resourced Site, Sampling

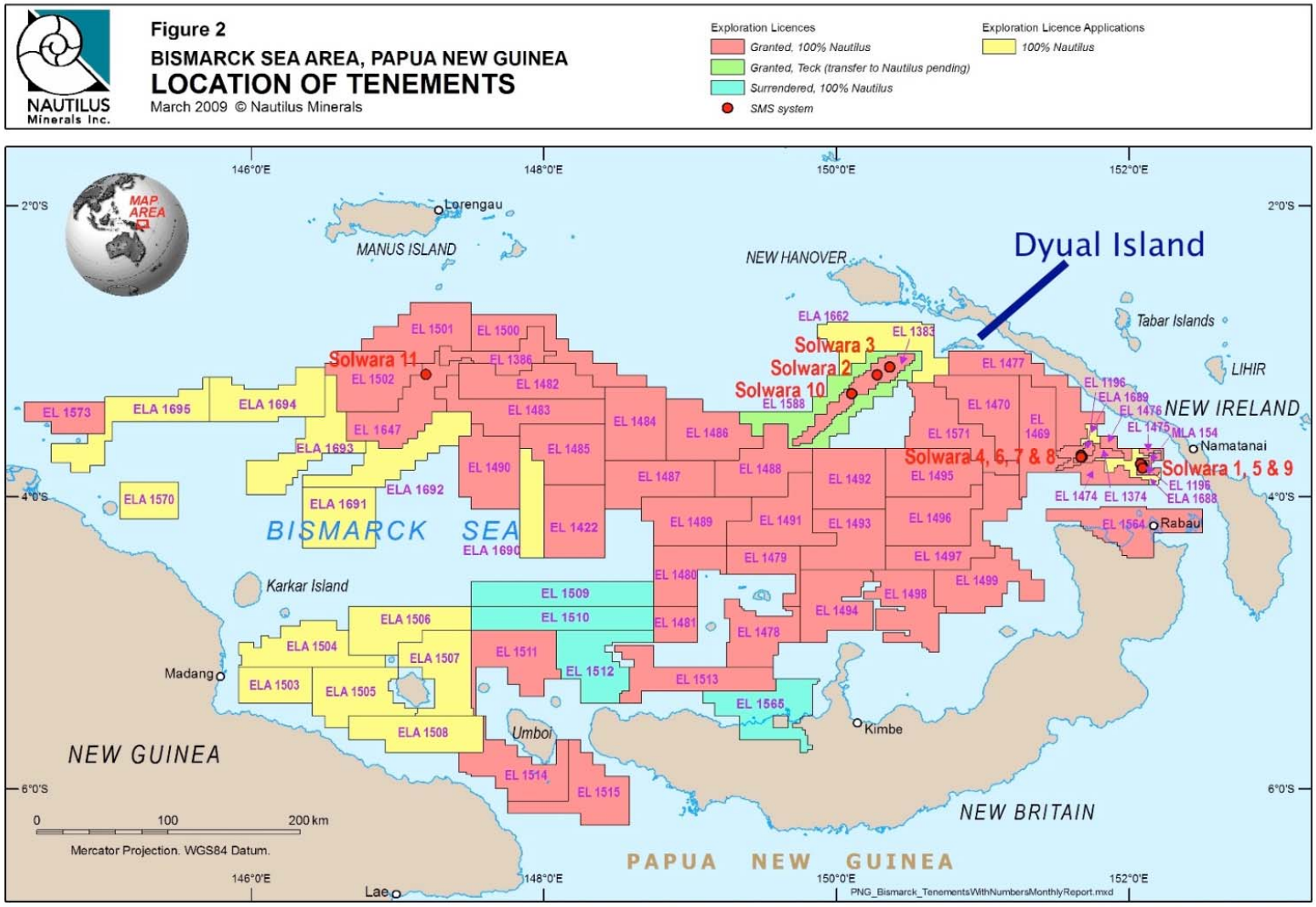
Effectiveness Study

Start Mining/ Confirmation

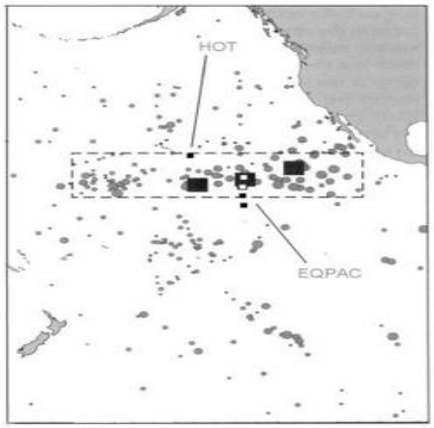
Excavation

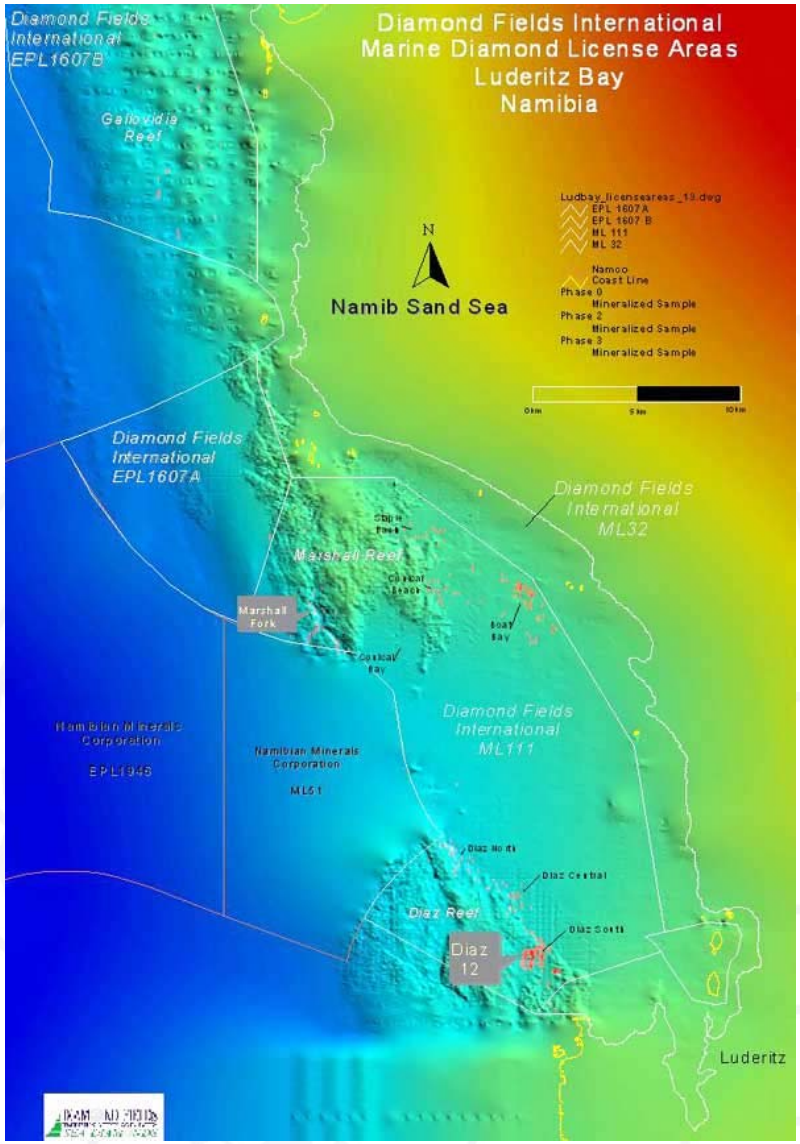
Operation/ Expansions

Search/Explore

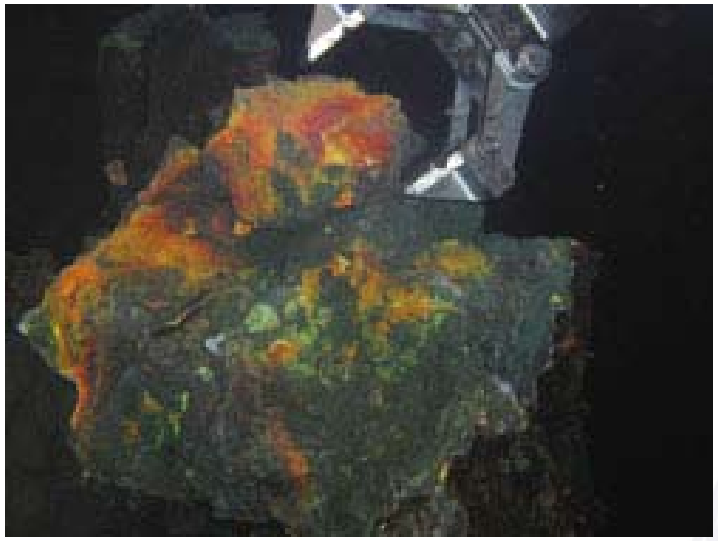


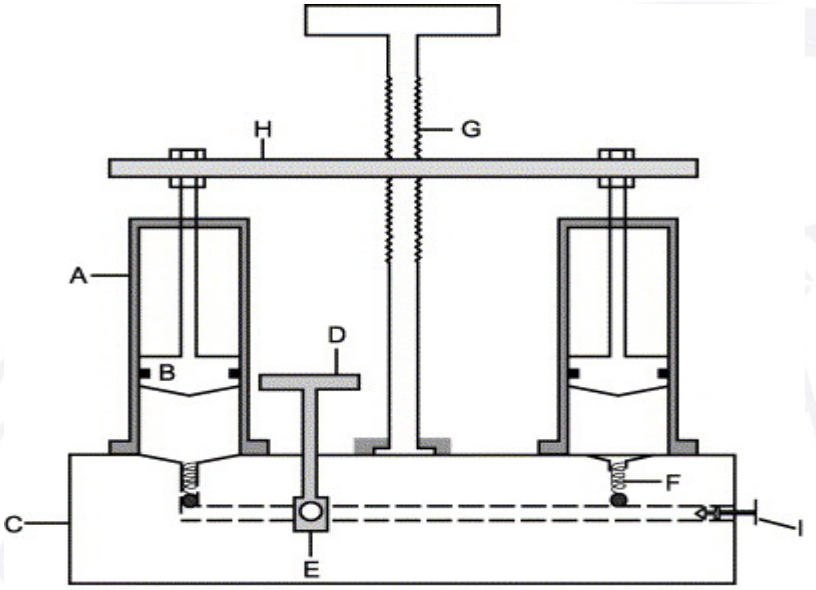
Search/Explore





Location of Resourced Site, Sampling

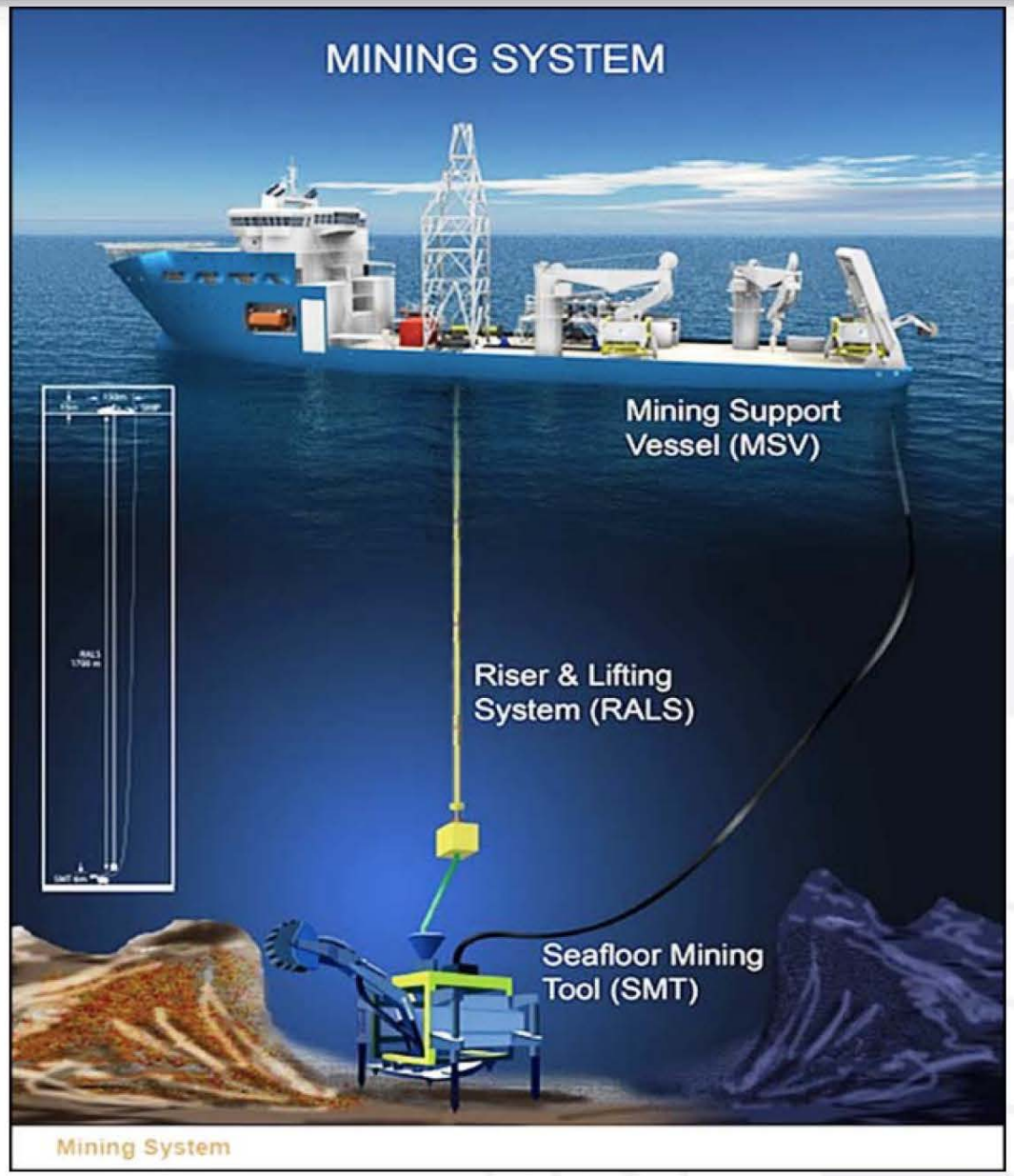




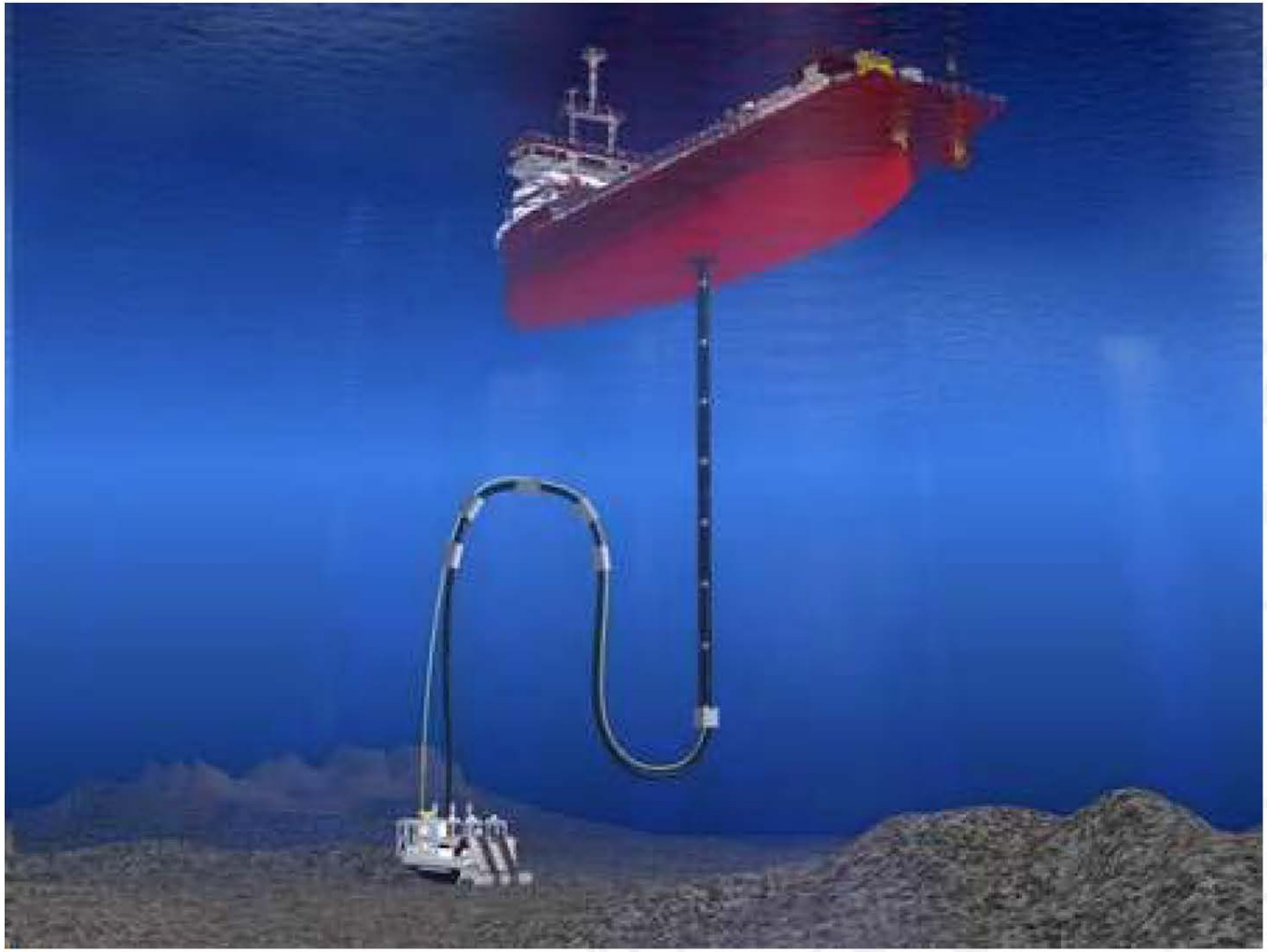
Excavation , Operation/ Expansions

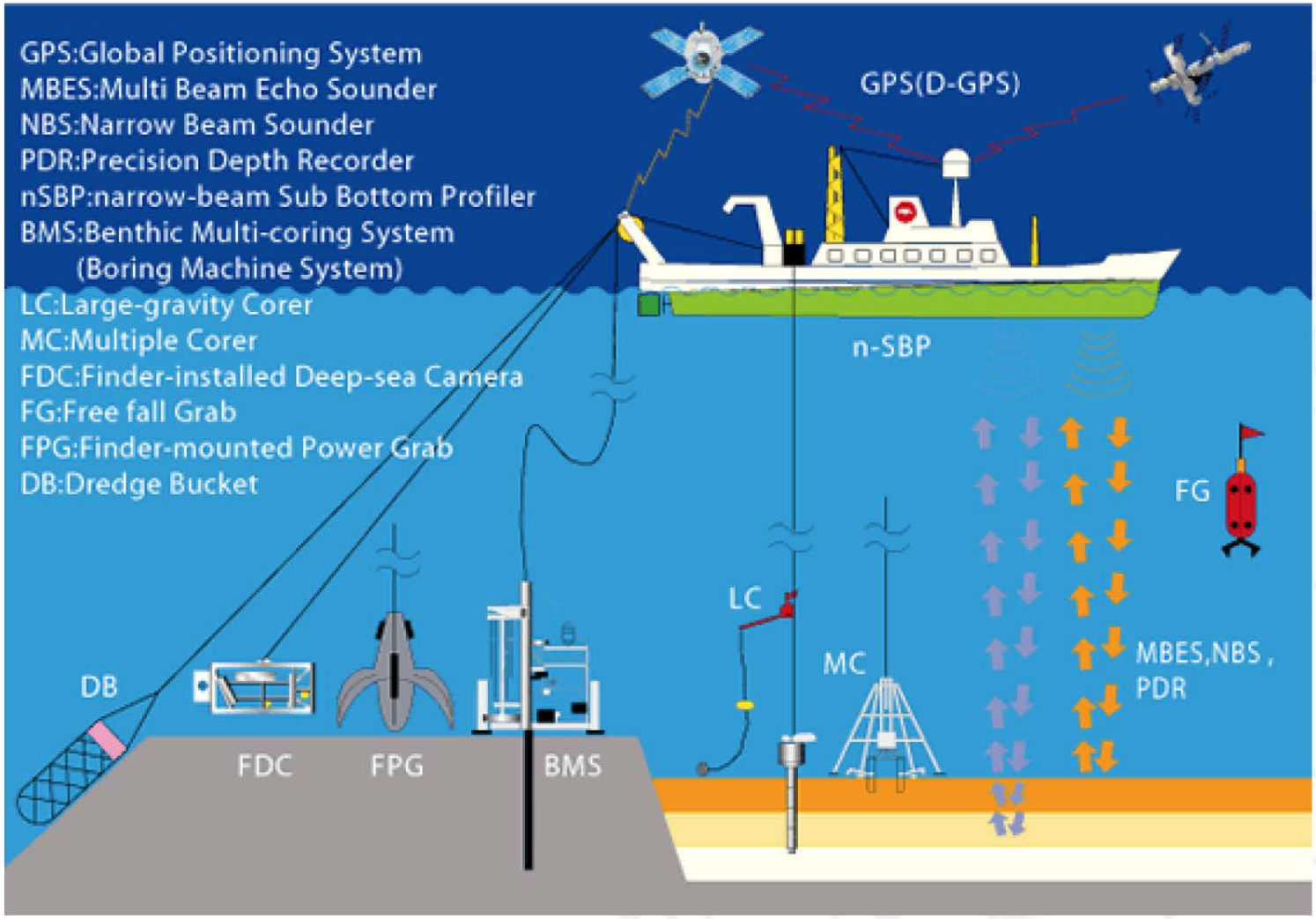
Oil Rig off Santa Barbara. ©Wolcott Henry 2001

Deep Sea Mining Vessels



Mining System




GPS:Global Positioning System
MBES:Multi Beam Echo Sounder
NBS:Narrow Beam Sounder
PDR:Precision Depth Recorder
nSBP:narrow-beam Sub Bottom Profiler
BMS:Benthic Multi-coring System
(Boring Machine System)
LC:Large-gravity Corer
MC:Multiple Corer
FDC:Finder-installed Deep-sea Camera
FG:Free fall Grab
FPG:Finder-mounted Power Grab
DB:Dredge Bucket
GPS(D-GPS)
n-SBP
FG
LC
MC
MBES,NBS ,
PDR
DB
FDC
FPG
BMS

Underwater Robot System

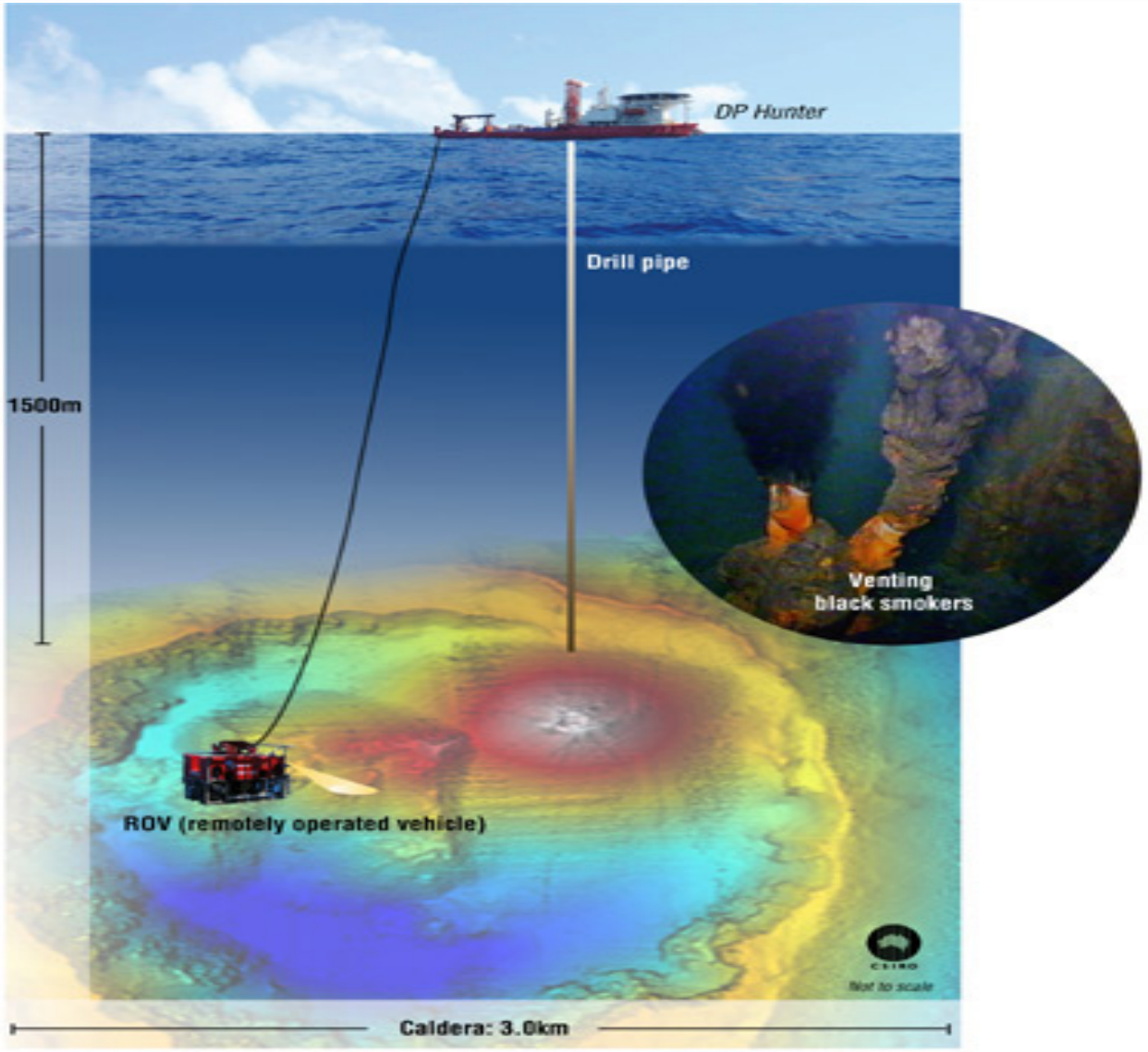
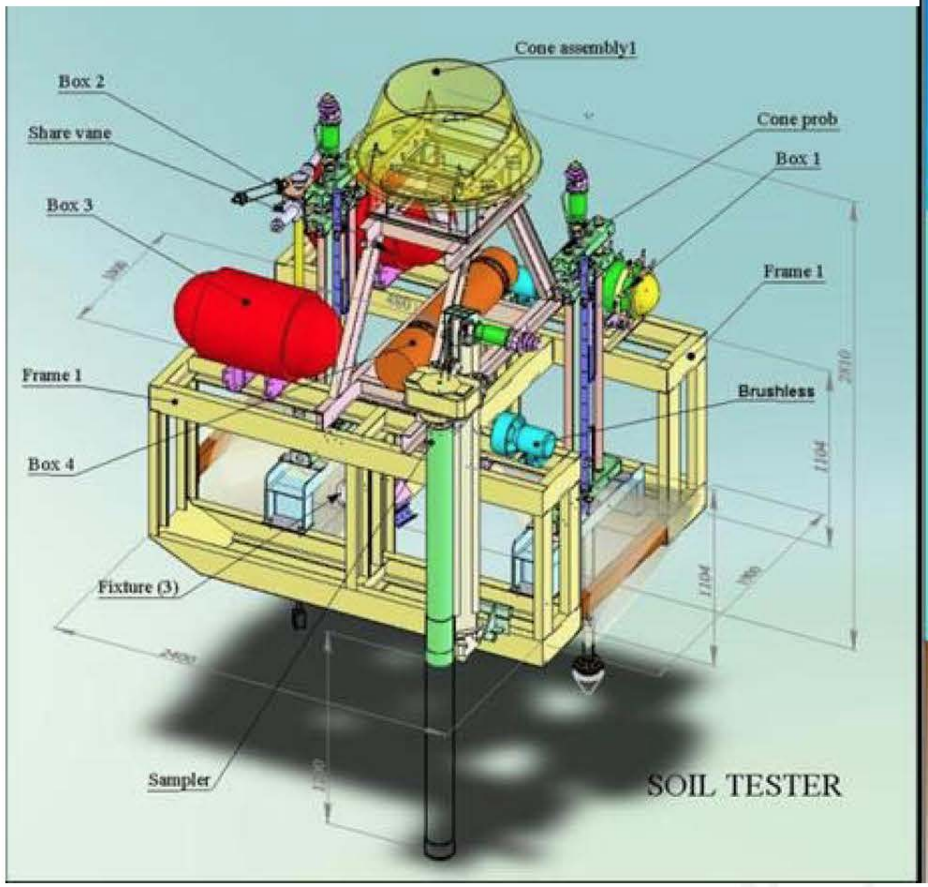
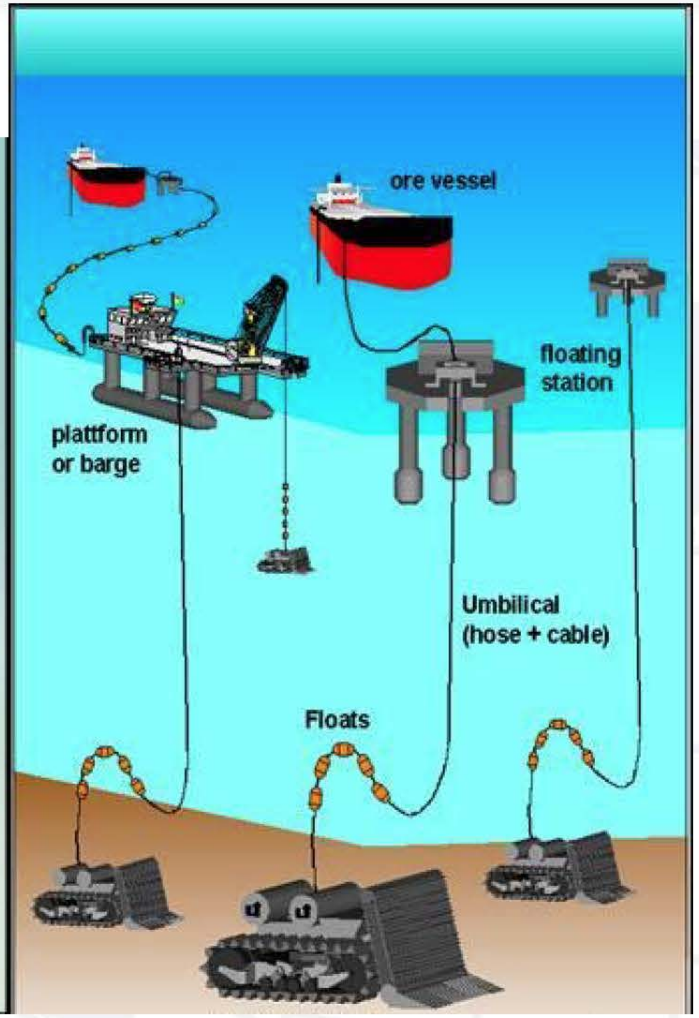


Image courtesy of CSIRO


Cone assembly1
Box 2
Share vane
Box 3
Cone prob
Box 1
Frame 1
Frame 1
Brushless
Box 4
Fixture (3)
Sampler
SOIL TESTER


ore vessel
floating
station
plattform
or barge
Umbilical
(hose + cable)
Floats

Difficulties in Undersea Mining

Deep water/ Darkness/ Current/ Unknown Environment

Extra High Water Pressure

Exploration/ Search difficulties

Detection/ Sampling of Resources

Approaching to the Underwater Sites

No Human Allowed Environments

Mining Method/ What Kind of Tools to Use..

Etc…….

Current Undersea Mining Technology

Undersea Drilling

Human Operated Submergible

Remotely Operated Underwater Vehicle

Mixed with Man-Machine Operations

Very Few options for Disaster (Oil Spill in 2011)

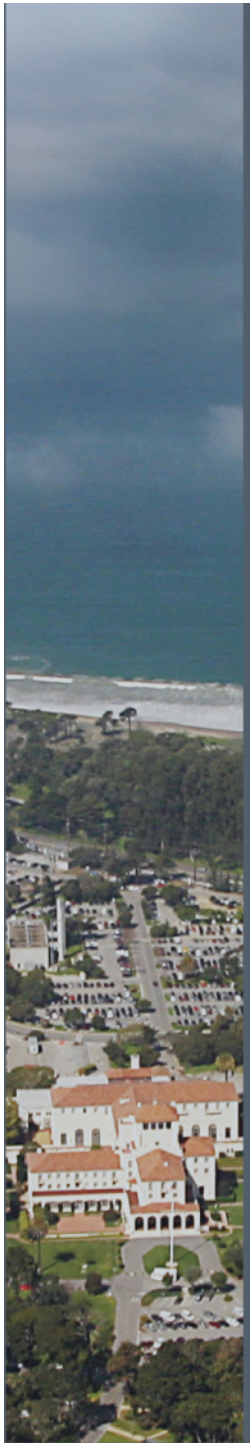
Future Directions

SMART Underwater Robot

Safe Underwater Oil Drilling

Accidents/ Disaster Prevention Measures

Sustainability and Effectiveness of Operation



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(2) Smart Underwater Robot (SUR) Technology

Why ?

- Entering a hostile or deep area (man cannot go) and gathering much information
- Quickly identifying possible mining areas and safe paths gathering, transmitting
- Continuous operations at the ocean floor
- Avoid any human related accidents
- High efficiency in operations

Definition of Smartness

From *Dictionary*

* Intelligent, Clever/Expert
* **Machines uses computer technology to make them effective.**
* Wisdom, 智慧/知慧
* 지혜는 이치를 깨우치고 사물을 정확하게 처리하는 정신적 능력

Ingredients of Smartness

- Agile Body/Vehicle Structure
- Mission Management System (Vehicle Management)
- Intelligent Navigation System (Obstacle Avoidance)
- Simultaneous Location and Mapping (SLAM) →
  Perception of Environment
- Target/ Object Recognitions
- Effective Mission Accomplishment
- Effective Networked/ Communication
- Swarm/Cooperative Operation? Maneuvering
- Cost Effectiveness

Undersea Mining Characteristics

- **Effective Search/ Confirming the Site**
- **Excavation and Development Stability**
- **Delivery of Ore and Resource**
- **Mining System/Complex Operation**
- **Sensitivity in Environmental Issues**
- **Disaster Prevention and Recovery**
- **Networked Communications**
- **System of Systems Management**

SMART Underwater Robot

- Intelligent/Effective Performances
- Overall Mission Management System
- Smart Vehicle Operations
- Obstacle Avoidance/Management
- Intelligent Perception of Environment
- High Probability in Recognition of Target/Object
- Sustainability/Interoperability

System Autonomy

Rule #1 → Gain information about the environment

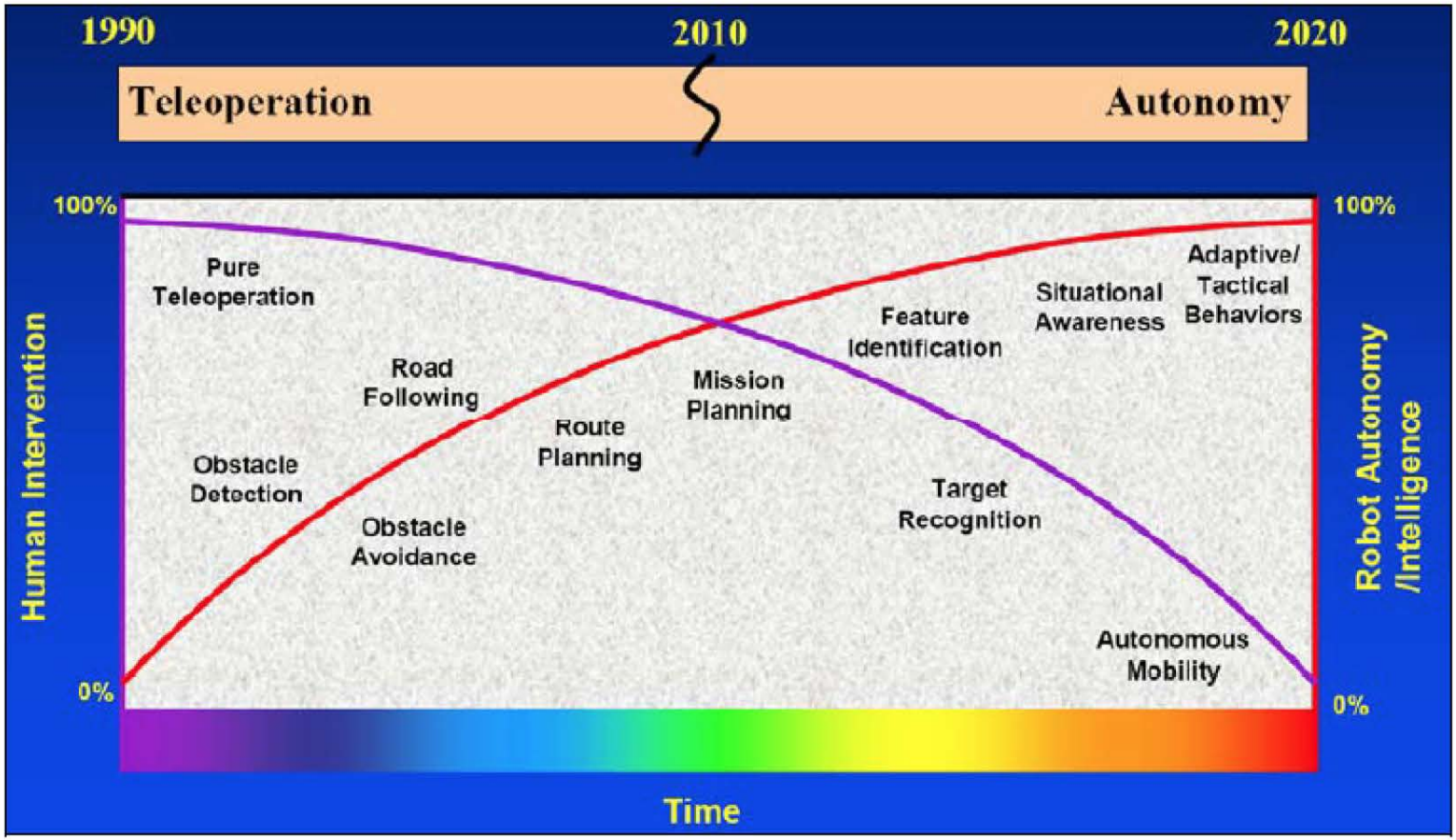
Rule #2 → Work for an extended period without human intervention

Rule #3 → Move either all or part of itself throughout its operating environment without human assistance

Rule #4 → Avoid situations that are harmful to people, property, or itself

Rule # 5 → Maintain its own survival at the expense of the previous rules (Sentient Robot Mandate)

Rule #6 → Learn or gain new capabilities like adjusting strategies for accomplishing its task(s) or adapting to changing surroundings.



Projected Evolution of the Level of Autonomy in Unmanned Vehicles from 1990 to 2020 (From: JRP, 04)

Endurance and Sustainability

Unmanned Systems

ONR — Revolutionary Research . . . Relevant Results

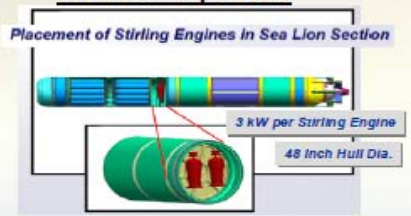
Unmanned Air Vehicle Power

- Long endurance fuel cell power (26 hr flight Nov 2009)
- Low noise & heat signature
- Affordable ($80K/vehicle)

Unmanned Undersea Vehicle Power

- Lithium-ion battery safety
- Air independent power systems: fuel cell, hybrid electric, Al-water

ONR Swampworks



Unmanned Surface Vehicles

- Advanced platform designs
- Launch & recovery
- Autonomous operation

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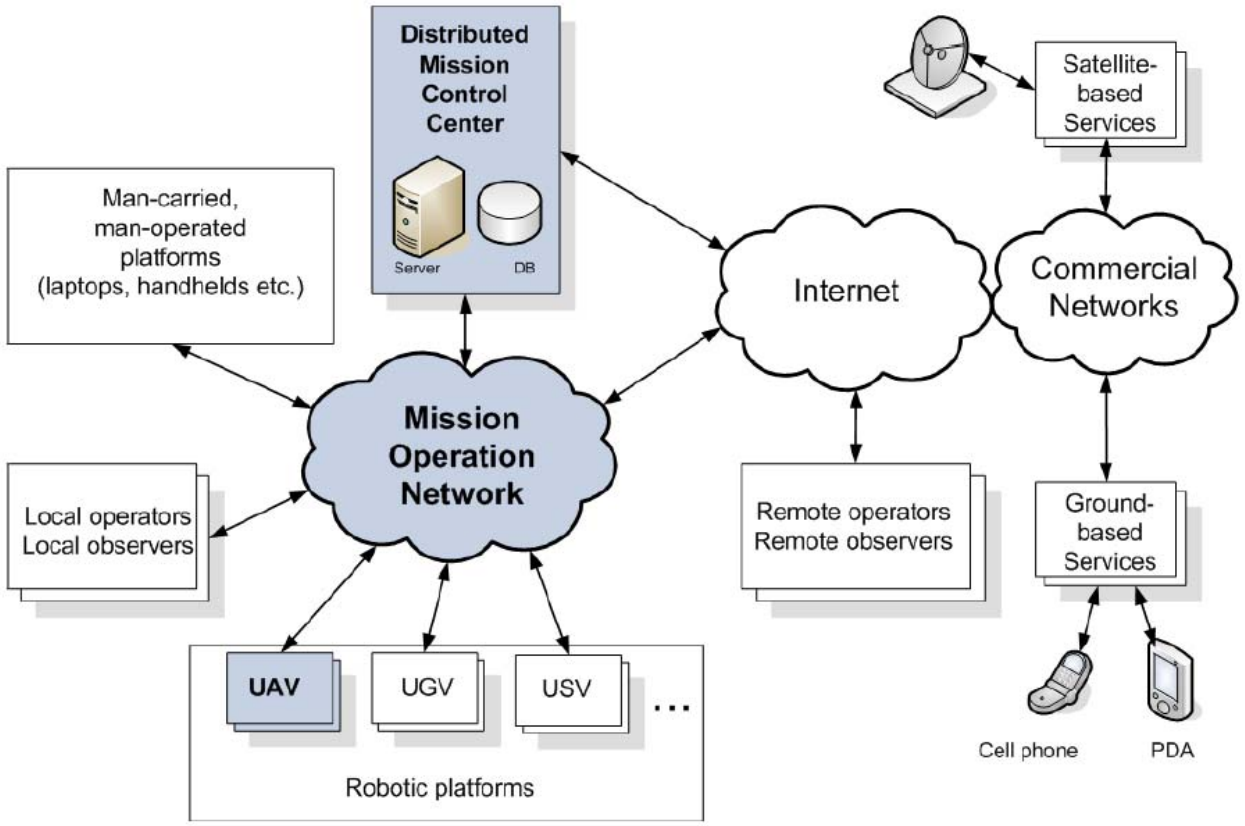
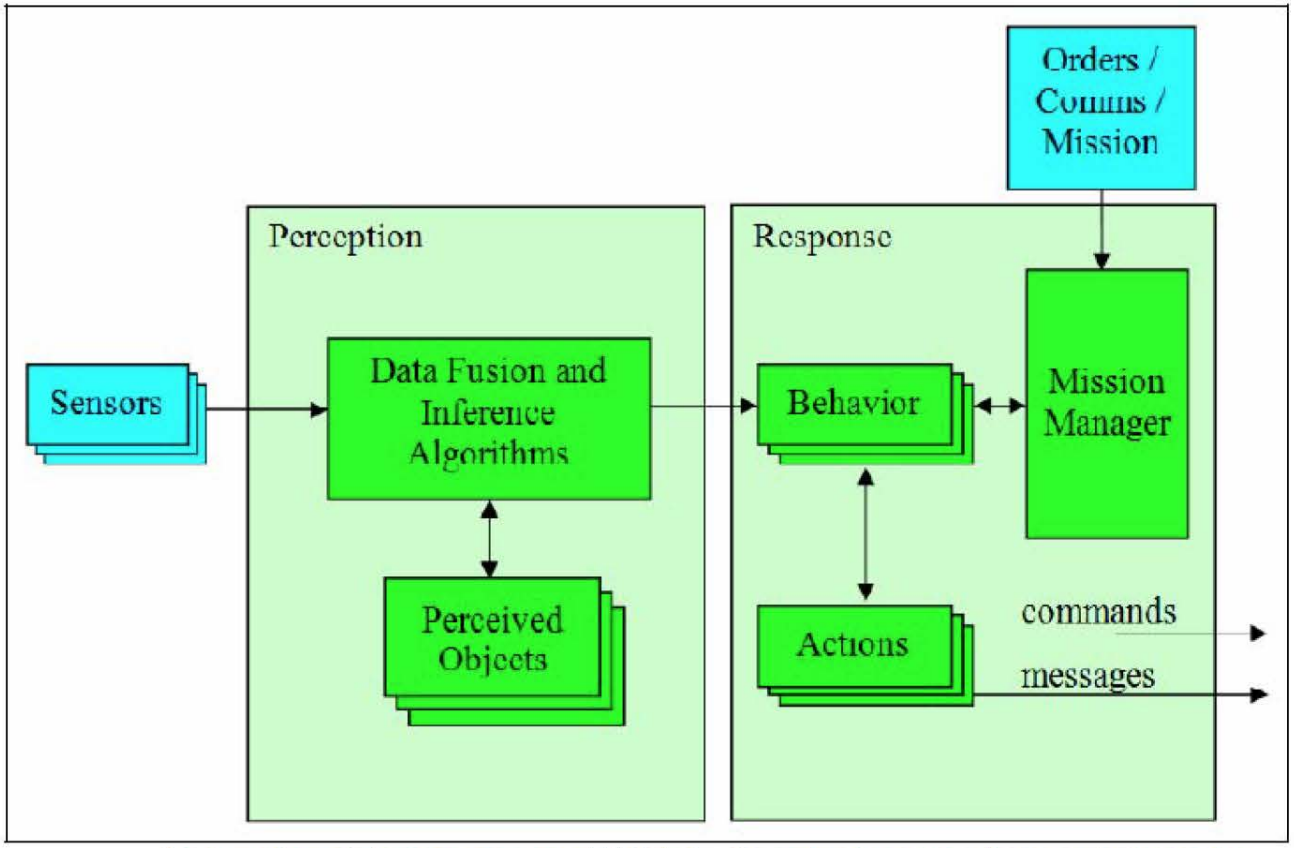
Networked Communication Systems



Network-Centric architecture overview.

System Mission Management Systems

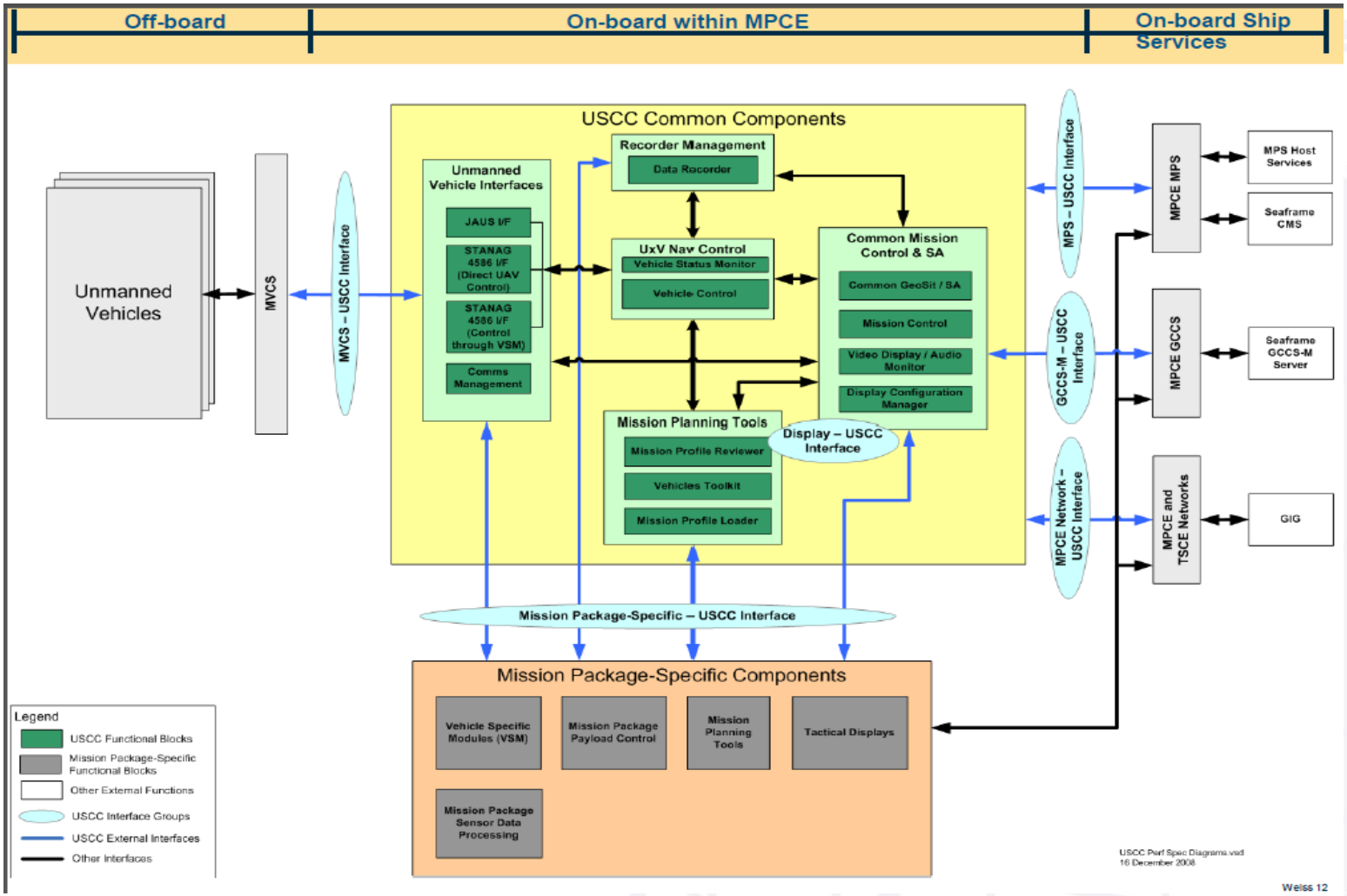
- Improved Performance
- Informed Decisions
- Smarter Control
- Better Resource Efficiencies
- Superior Responsiveness
- Reduced communication Requirements



Behavioral Autonomous Vehicle Control as Implemented in the Pennsylvania State University Applied Research Laboratory Intelligent Control Architecture (After: Lewis and Weiss, 04)

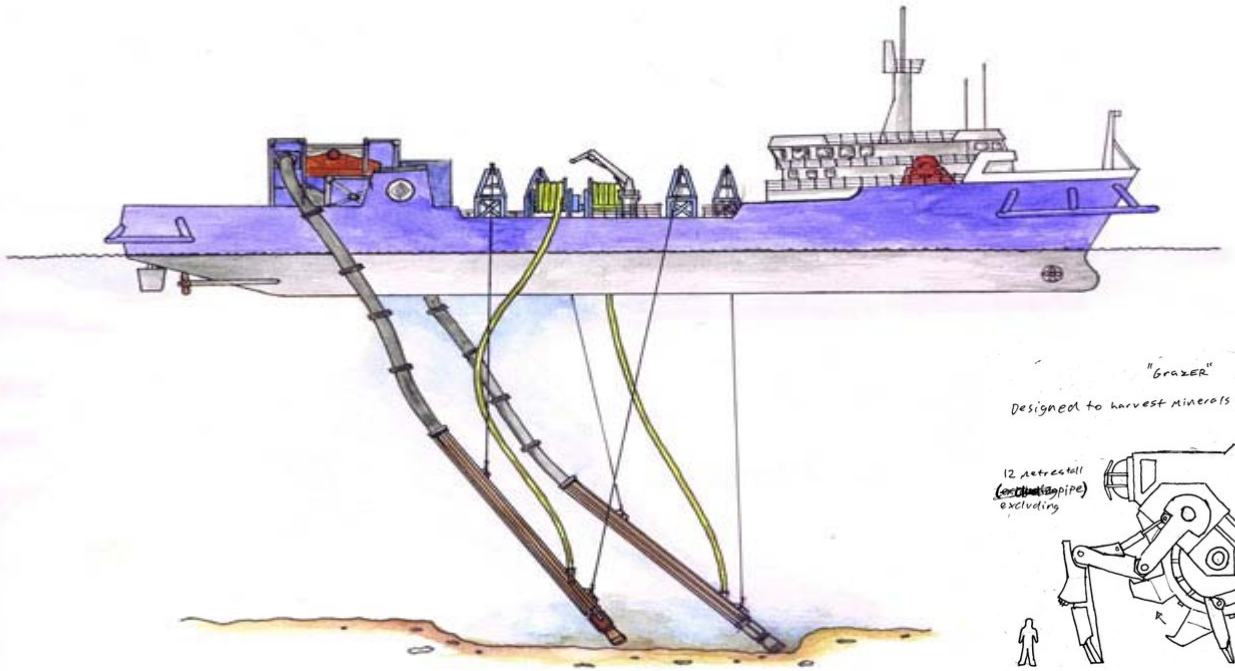
Intelligent Navigation

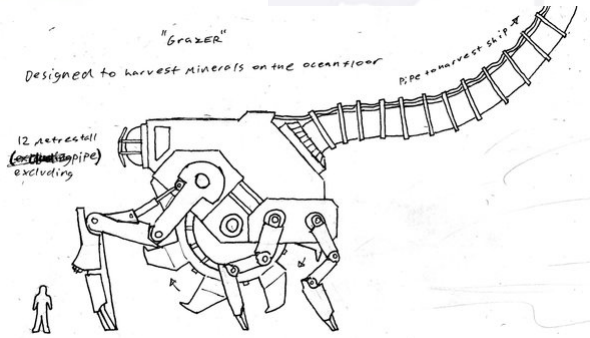
Smart Mission Management System



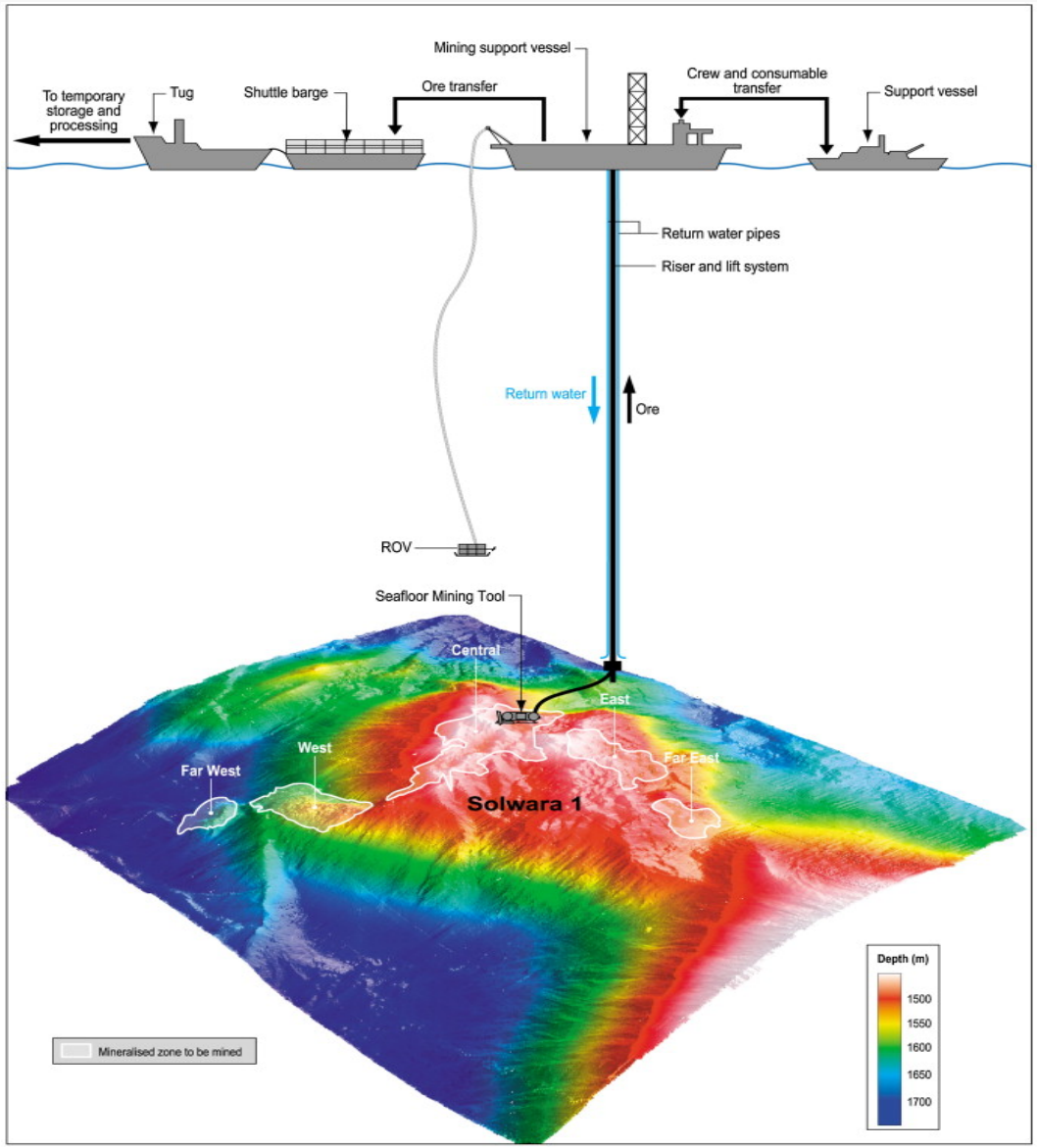
Future Prospective for Undersea Mining

Shallow Water Zone

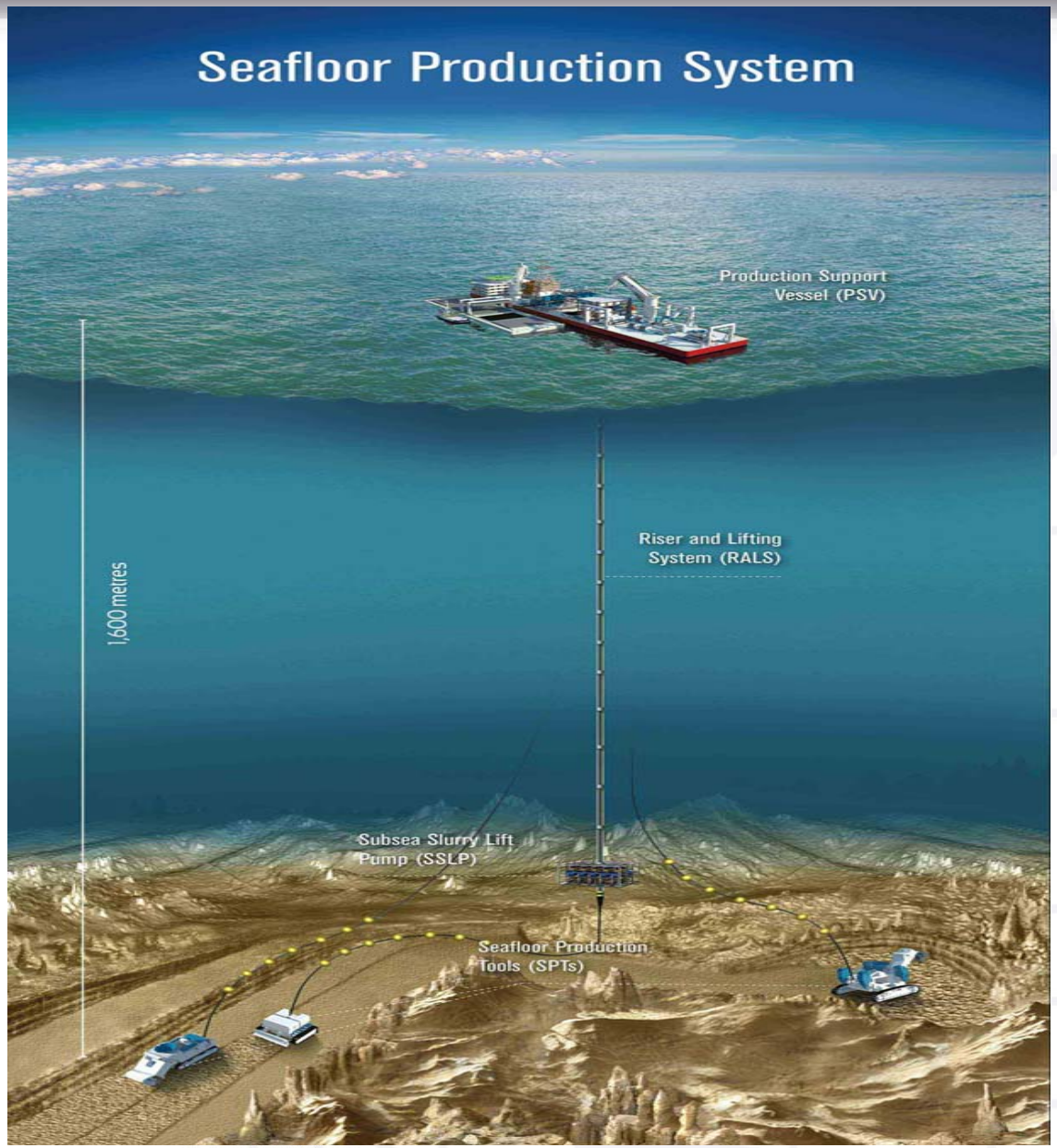


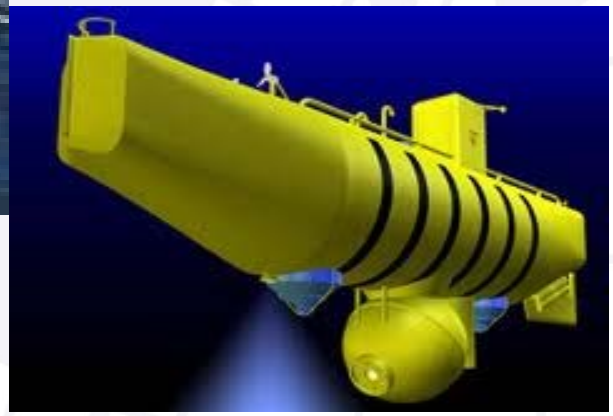


Medium Depth Sea Mining

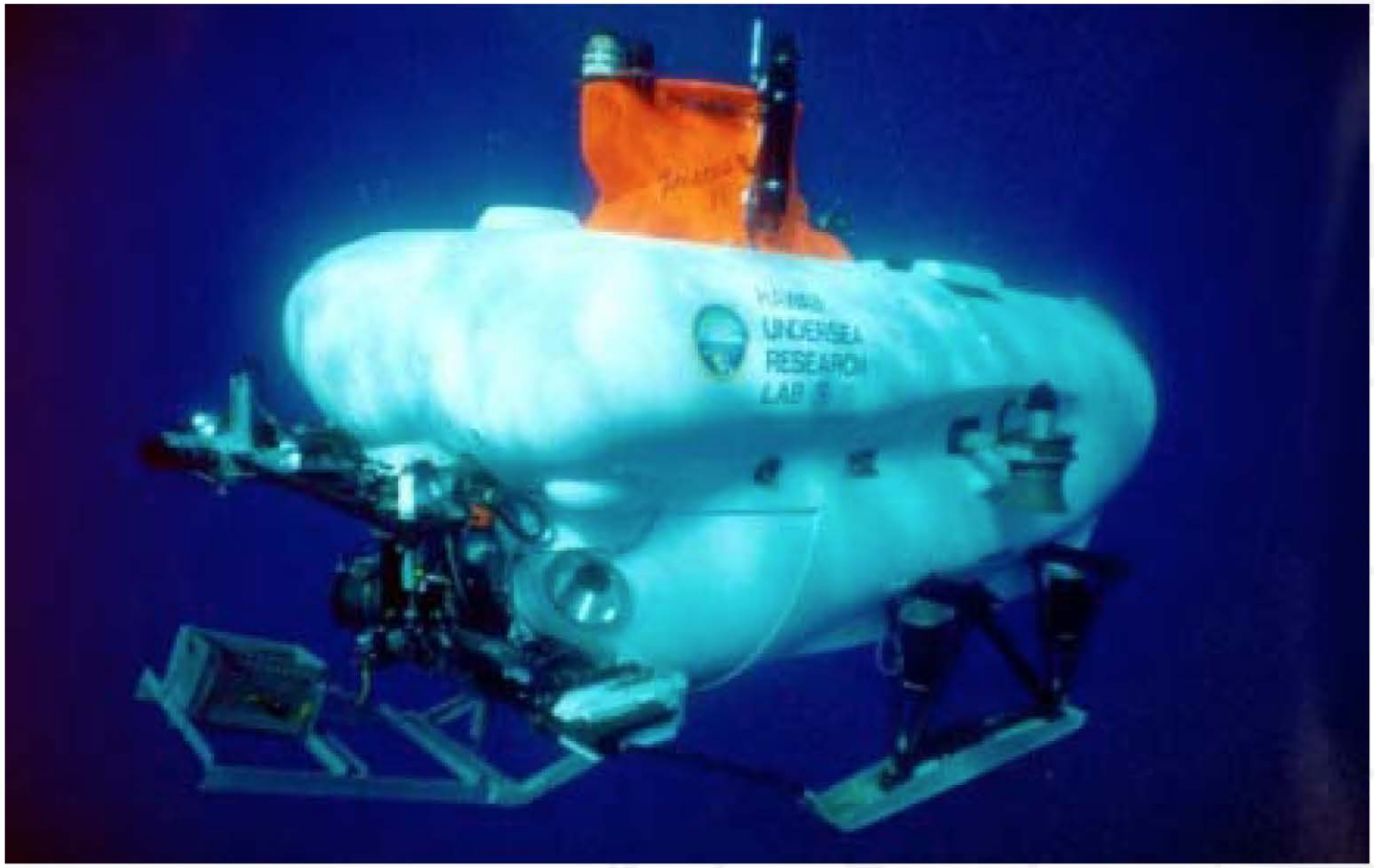


Medium and Deep Sea Mining





Deep Sea Explorer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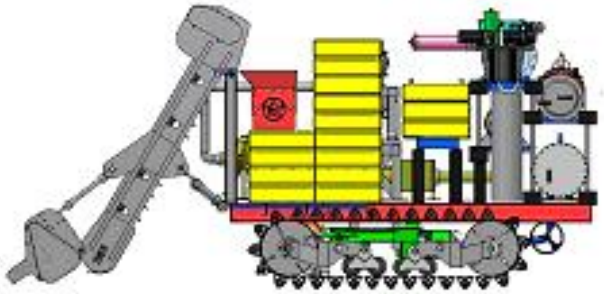
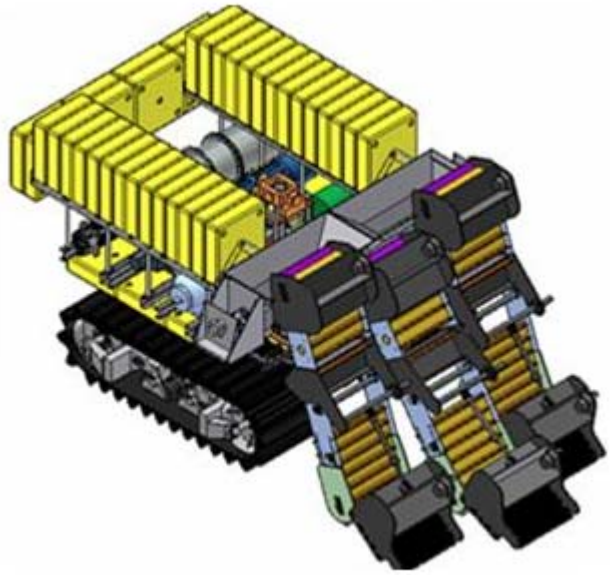
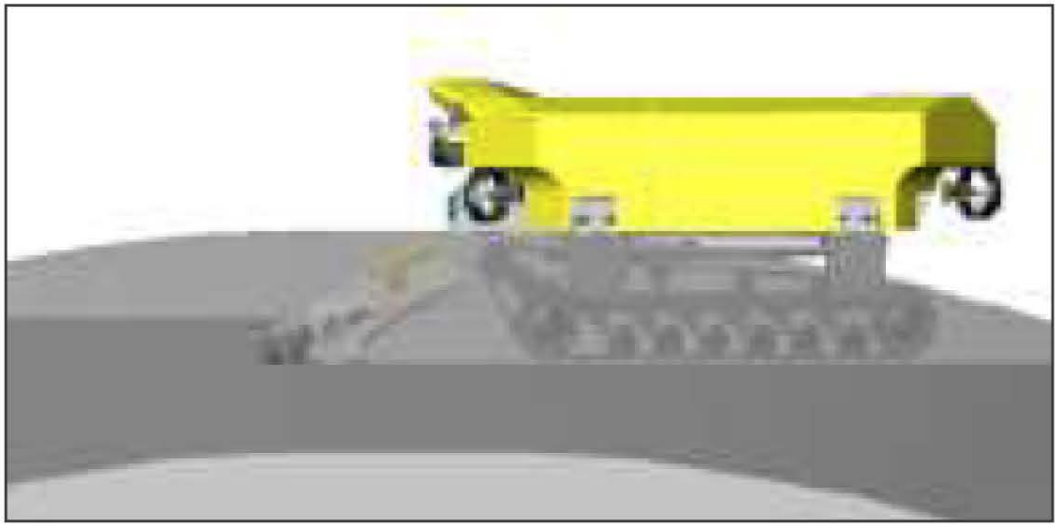
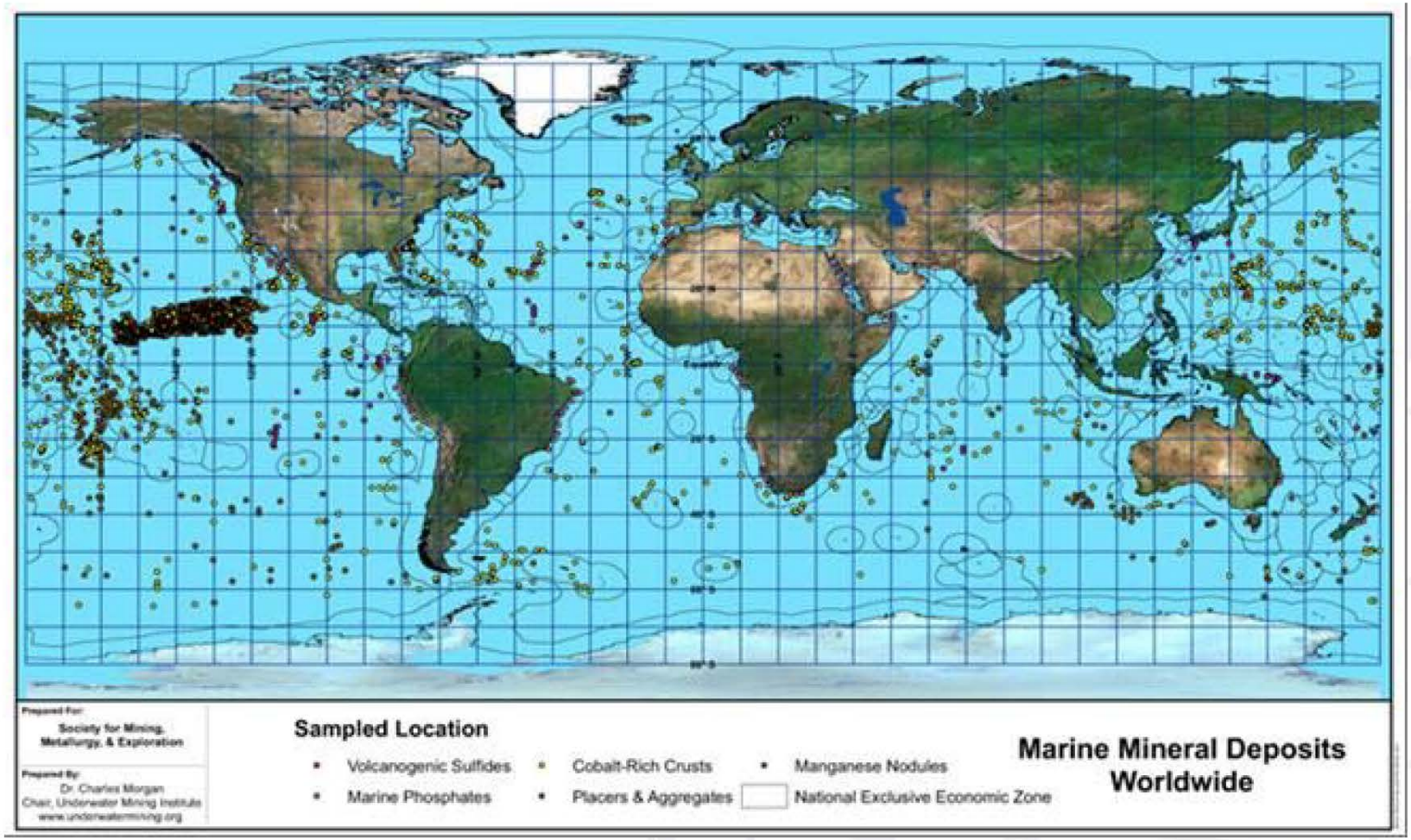
Sea Floor Unmanned Excavation Vehicle





Nautilus has investigated the use of proven subsea technology for mining the SMS deposits. This 900HP ROV oil/gas pipelay trenching machine is as powerful as a D11 bulldozer.




Prepared For:
Society for Mining, Metallurgy, & Exploration
Prepared By:
Dr. Charles Morgan
Chair, Underwater Mining Institute
www.underwatermining.org
Sampled Location
Volcanogenic Sulfides
Cobalt-Rich Crusts
Manganese Nodules
Marine Phosphates
Placers & Aggregates
National Exclusive Economic Zone
Marine Mineral Deposits Worldwide

Questions and Future Cooperation?

Thank you for your attention.